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Fall vortex ozone as a predictor of springtime total ozone at high northern latitudes

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Abstract. Understanding the impact of atmospheric dynamical variability on observed changes in stratospheric O_3 is a key to understanding how O_3 will change with future climate dynamics and trace gas abundances. In this paper we examine the linkage between interannual variability in total column O_3 at northern high latitudes in March and lower-to-mid stratospheric vortex O_3 in the prior November. We find that these two quantities are significantly correlated in the years available from TOMS, SBUV, and POAM data (1978–2004). Additionally, we find that the increase in March O_3 variability from the 1980s to years post-1990 is also seen in the November vortex O_3, i.e., interannual variability in both quantities is much larger in the later years. The cause of this correlation is not clear, however. Interannual variations in March total O_3 are known to correspond closely with variations in winter stratospheric wave driving consistent with the effects of varying residual circulation, temperature, and chemical loss. Variation in November vortex O_3 may also depend on dynamical wave activity, but the dynamics in fall are less variable than in winter and spring. We do not find significant correlations of dynamic indicators for November such as temperature, heat flux, or polar average total O_3 with the November vortex O_3, nor with dynamical indicators later in winter and spring that might lead to a connection to March. We discuss several potential hypotheses for the observed correlation but do not find strong evidence for any considered mechanism. We present the observations as a phenomenon whose understanding may improve our ability to predict the dependence of O_3 on changing dynamics and chemistry.

1 Introduction

The polar regions are a bellwether for processes that affect stratospheric O_3 globally. Decadal decreases in total O_3 at high southern latitudes in spring (Fig. 1) are clearly attributable to increasing abundances of chlorine- and bromine-containing trace gases of anthropogenic origin, which are now regulated by international agreements (Solomon, 1999 and references within). Owing to more active meteorology in the northern hemisphere (NH), springtime O_3 decreases there are not as monotonic as those in the South (Fig. 1) and are attributed to a combination of chemical and dynamical forcings (Newman et al., 1997; Manney et al., 1997; Coy et al., 1997; Chipperfield and Jones, 1999; Anderson and Knudsen, 2002). The relative contribution, causal mechanisms, and time scales for dynamical O_3 change at high northern latitudes, as well as in the middle latitudes of both hemispheres, is currently the subject of active scientific debate (WMO, 2003).

During winter, O_3 is transported from the low-latitude photochemical production region by the poleward and downward Brewer-Dobson circulation. This circulation is primarily driven by planetary scale waves propagating into the stratosphere from the Northern extratropical troposphere (Rosenlof and Holton, 1993). These planetary waves affect polar O_3 is three ways: 1) directly, as noted above, by the Brewer-Dobson circulation which advects higher concentrations of O_3 into the lower stratosphere, 2) by occasionally mixing material into the polar vortex or by breaking up the polar vortex, and 3) indirectly by warming the polar region and reducing the occurrence of polar stratospheric clouds, which thereby decreases catalytic chemical loss of O_3. Interannual variation of planetary wave activity has a major effect on O_3 levels in spring via both transport and photochemical loss.

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